

Asymmetry measurement of charged hadron production in $p\uparrow A$ collisions at 40 GeV

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Abstract

The single spin asymmetry of charge hadron production by a 40 GeV proton beam with 39% transverse polarization incident on nuclei (C, Cu) has been measured using the Focusing Double Arm Spectrometer (FODS). The measurements were carried out for hadrons with high x_T (82° in c.m.) and with high x_F (one arm at 51° and the other arm at 99° in c.m.). The results are presented for charged pions, kaons, protons and antiprotons with high x_T .

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We have measured the single-spin asymmetry A_N of the inclusive charged pion, kaon, proton and antiproton production cross sections at high x_T and high x_F for a 40 GeV/ c proton beam incident on nuclei (C, Cu), where A_N is defined as

$$A_N = \frac{1}{P_B \cdot \cos\phi} \cdot \frac{N\uparrow - N\downarrow}{N\uparrow + N\downarrow}, \quad (1)$$

where P_B is the beam polarization, ϕ is the azimuthal angle of the production plane, $N\uparrow$ and $N\downarrow$ are event rates for the beam spin up and down respectively. The measurements were carried out at IHEP, Protvino. The polarized protons are produced by the parity - nonconserving Λ decays [1]. The up or down beam transverse polarization is achieved by the selection of decay protons with angles near 90° in the Λ rest frame by a movable collimator. At the end of the beam line two magnets correct the vertical beam position on the spectrometer target for the two beam polarizations. The intensity of the 40 GeV/ c momentum polarized beam on the spectrometer target is 3×10^7 ppp, $\Delta p/p = \pm 4.5\%$, the transverse polarization is $39^{+1}_{-3} \%$, and the polarization direction is changed each 18 min during 30 s. The beam intensity and position are measured by ionization chambers and scintillation hodoscopes. Two Cherenkov counters identify the beam particle composition to control background contamination. At the spectrometer magnet entrance there are two scintillation hodoscopes to measure the vertical coordinates of particles emitted from the target.

The measurements have been carried out with the FODS [1] spectrometer. It consists of an analyzing magnet, drift chambers, the Cherenkov radiation spectrometer (SCOCH) for particle identification (π^\pm , K^\pm , p and \bar{p}), scintillation counters and hadron calorimeters to trigger on the high energy hadrons. To further suppress a background there are two threshold Cherenkov counters using air at atmospheric pressure inserted in the magnet. Inside the magnet there is also a beam dump made of tungsten and copper. There are two arms which can be rotated around the target center situated in front of the magnet to change the secondary particle angle. The Cherenkov radiation spectrometer consists of a spherical mirror with diameter 110 cm, 24 cylindrical lenses to focus the Cherenkov light on the hodoscope photomultipliers. Measuring the particle velocity using the SCOCH and its momentum in the magnetic field one can determine the particle square mass M^2 . The SCOCHs are filled with Freon 13 at 8 atm.

In 1994 a study of the single spin asymmetry (A_N) in inclusive charge

hadron production was started using FODS:

$$p \uparrow + p(A) \rightarrow h^\pm + X, \quad (2)$$

$$p \uparrow + p(A) \rightarrow h^\pm + h^\pm + X, \quad (3)$$

where h^\pm is a charged hadron (pion, kaon, proton or antiproton). The experimental program consists of measuring the charge hadron single spin asymmetry at high x_T and x_F in pp and pA collisions to study the asymmetry dependence on the quark flavors u, d, s and kinematical variables.

The pilot measurements of A_N for the charged hadrons carried out in 1994 on a hydrogen target for small x_F [1] are presented below for comparison with data obtained with nuclei.

The measurements of A_N in the range $-0.15 \leq x_F \leq 0.2$ and $0.5 \leq p_T \leq 4$ GeV/ c are carried out with symmetrical arm positions at angles of ± 160 mrad. The results of the two arms are averaged, which partially cancels systematical uncertainties connected with the variation of the beam position in the vertical direction, the intensity monitor and the apparatus drift.

Figure 1a depicts the π^+ meson production asymmetry. Within the errors there is no difference of A_N for both targets (C and Cu). A_N for the nuclear targets in the range $1 \leq p_T \leq 2$ GeV/ c is approximately 4% higher than for the hydrogen target. For the central region such a difference can be connected with the smaller portion of u quarks in the nuclear target containing neutrons. Fragmentation of u quarks ($u \rightarrow \pi^+$) from the polarized beam protons as well as u quarks of the target contribute to the asymmetry. Because the target protons are not polarized their contribution in the central region reduces the measured polarization. For nuclear targets containing less u quarks in comparison with d quarks the decrease of the asymmetry is not so substantial. Quark scattering in nuclei must also lead to the decrease of the asymmetry.

The asymmetry for π^- meson production is presented in Figure 1b. In the range $0.9 \leq p_T \leq 1.6$ GeV/ c it is about 4% higher for the nuclear targets than for the hydrogen target. For the central region such differences can be connected with the larger proportion of d quarks in the nuclear targets. The major fragmentation contribution give d quarks ($d \rightarrow \pi^-$) from polarized beam protons and the target. For π^- mesons in pp collisions the asymmetry is therefore negative. Due to the large contribution of the unpolarized target in the central regions the asymmetry for nuclear targets is shifted into the positive region.

Figure 1c shows the asymmetry for K^+ production. There is no significant difference in A_N for the two nuclear targets (C and Cu) and A_N is about 3% higher than for the hydrogen target. The reason for this can be the same as for π^+ mesons.

Figure 1d presents A_N for K^- mesons. Within the errors there is no appreciable difference in A_N for all targets (p, C and Cu) and A_N is close to zero. This is expected because K^- does not contain valence quarks from the beam proton.

Figure 1e depicts the asymmetry for proton production which is close to zero in nuclear targets. For the hydrogen target it is slightly negative.

The asymmetry for antiproton production presented in Figure 1f shows no difference for all targets (p, C and Cu) and is close to zero. This result is expected because the produced antiproton does not contain valence quarks from the beam proton. Sea quarks in most models are expected to be unpolarized. The upper limit for the asymmetry for antiprotons and K^- mesons is given by the sensitivity of the experiment (4%).

Two features of the results can be stressed:

1. There is no significant difference for the two nuclear targets (C, Cu);
2. For the positive charge mesons the asymmetry has a maximum at $p_T = 2.2$ GeV/ c and decreases to zero at $p_T = 2.9$ GeV/ c .

The analysis for high x_F is still under way.

References

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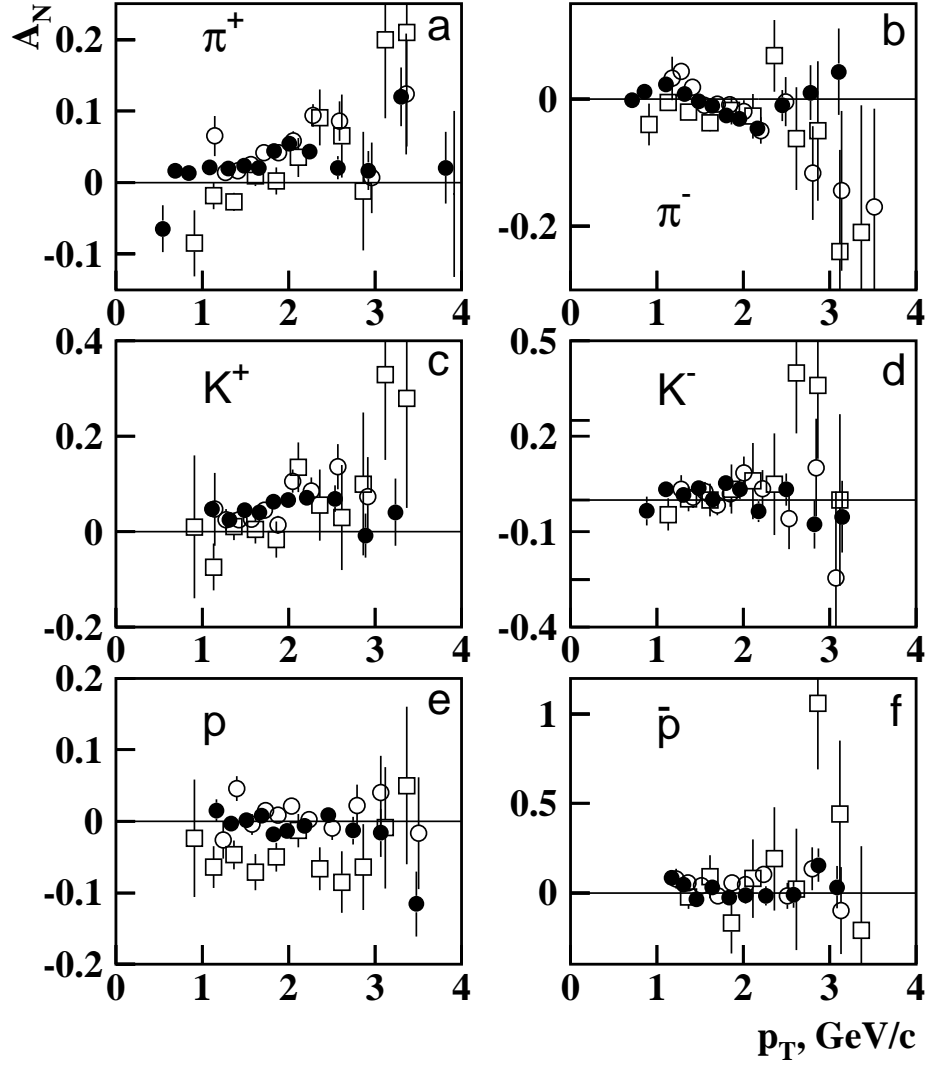


Figure 1: A_N dependence on p_T for $p \uparrow + p(A) \rightarrow h^\pm + X$, where $h = \pi^+$ (a), π^- (b), K^+ (c), K^- (d), p (e), \bar{p} (f). Closed circles correspond to C target, open circles - Cu, square - proton.